

STATE OF CHANGE Annotated Text and References

PAGE 2-3 Stories of Change from Alaska's National Parks

An Inuit proverb tells us, “We borrow the earth from our children.”ⁱ That’s a challenging legacy for a state in the midst of change.

From the breached banks of Yukon-Charley Rivers National Preserve to retreating rivers of ice in Kenai Fjords National Park, significant signs of change can be found across Alaska’s national parks.ⁱⁱ

Change isn’t new. These parks have been in constant change for thousands of years. But in the past 150 years, the speed of change has accelerated.ⁱⁱⁱ Will our parks be able to keep up with rapid environmental changes?

To take care of these places, we turn to scientists to understand what is happening and to look for solutions. Their conclusion: the driving force behind the changes we’re seeing is carbon emissions from human activities^{iv}. Hope for the future lies in learning to adapt to these changes, even as we work together to reduce the underlying cause.^v

It’s time for a crucial conversation.

This guide is a conversation with people who visit and work around our national parks. It will help illustrate what we’re doing about the changing climate. You will find facts about the science, visible evidence you can see, examples of how parks are making a difference, and things you can do to make a difference too. We hope you’ll join this dialogue and help us better understand and take action to preserve these parks that we’ve borrowed from our children^{vi}.

Science Notes: How Do We Know That What We’re Seeing Is Climate Change?

First, what’s the difference between weather and climate^{vii}? Alaska author Charles Wohlforth says that, “Choosing shorts or long underwear on a particular day is about weather, the ratio of shorts to long underwear in the drawer is about climate.”^{viii} Scientists agree^{ix} that climate is changing on a global scale.^{x xi xii} They know this from thousands of scientific studies done around the world^{xiii xiv}, some right here in our parks^{xv xvi xvii xviii}. Greenhouse gases, including carbon dioxide, act like a blanket in the atmosphere, holding in the warmth of the sun and keeping the land and air around us from cooling off. There is now more carbon dioxide in the atmosphere than there has been for 3 million years^{xix}—and that level continues to rise rapidly. When we study park resources, we can’t point to any single event and say it’s caused by changing climate. Long-term trends tell the story.

Get Involved!

Throughout this book, we suggest meaningful ways that you can take action on climate change. The first step is educating yourself. To learn more about global climate change, scan the QR code or use the link below to visit the NASA climate change website: <http://climate.nasa.gov>

PAGE 4-5

Impressions to Last a Lifetime

What do visitors think about climate change in Alaska's parks?

Alaska's parks are famous for capturing the hearts and minds of people around the world. They're home to some of America's greatest natural wonders and shared heritage, but these treasured places could be very different in the future. Park visitors have an important role in managing these places and taking action during a time of change.

Natural Reflections

Alaska's national parks have the power to inspire and transform. Parks teach us about our connections to the world around us and the changes occurring around the state. In the future, how will the effects of climate change shape this learning experience? Which stories will best engage, inspire and challenge park visitors?

Reaching Out

The National Park Service (NPS) wants to raise awareness about climate change impacts occurring in parks and enlist visitors in addressing them^{xx}. Educational products such as exhibits, brochures, and interpretive programs help explain what we understand about climate change in the parks. Rangers and tour guides stay up-to-date on climate research, so they can help keep visitors and residents informed and engaged in planning for a changing future.

Mixed Emotions

Sometimes visitors feel mixed emotions or conflict about the changes they see in parks. On the adjoining page, three travelers share how Alaska's beauty and the people they met during their visits gave them a new awareness to take home and remember long after their trip.

"We can see some of the impacts of climate change in California, but it was really evident throughout our trip to Alaska. It's just obvious that it's happening. Every time we went to a glacier, there were pictures and signs of what the glacier used to look like and what it looks like now. It really brought it home. We need to know what individuals can do about this problem."

- Blair, from California

"It was an "oh my goodness" moment for me. Climate change is such an abstraction; it's hard for people to grasp what it means. You can't see carbon, but when you see how much a glacier... has receded, it's really crystallized for me the effects of climate change. I used to go to the grocery store and get a plastic bag every time. I stopped doing that after my Alaska trip. I used to think, what difference does one person make? I felt a personal responsibility to do things differently after my trip to Alaska."

- Timothy, from Arkansas

"I grew up in Alaska and try to get back every few years. Each trip reveals how much the land...is changing. We landed in Anchorage on what seemed like an unusually warm evening. I casually asked the taxi driver about the weather and was surprised to hear him tick off all the ways that climate change was impacting Alaska. Everyone else I asked over the next week responded exactly the same way! With so many residents and visitors recognizing what's happening, it's time for less talk and more action."

- Christine, from Oregon

Get Involved!

What impressions have you gained from your visit? Including climate change as part of the story you bring home with you can help empower others to take action.

What to Look For: Exit Glacier Makes an Exit

Exit Glacier, in Kenai Fjords National Park, has receded two miles over the past 200 years. Like other low elevation glaciers, warming temperatures have caused it to steadily lose more ice than it gains each year. The glacier has also thinned a lot in the past century. Exit Glacier is visited by hundreds of thousands of people each year, and access to the shrinking glacier will become more challenging as it continues to recede. Park rangers have had to move signs and paths to accommodate visitors.^{xxi}, ^{xxii}

Taking it All In

Visitors take a boat tour to the Holgate Glacier in Kenai Fjords National Park.

PAGE 6-7

Going, Going...

Why are Alaska's glaciers disappearing so fast?

What was on the top of your list of things to see and do during your visit to Alaska? If you are like many other visitors to the state, you wanted to see a glacier. Seeing a glacier in a photo or a movie clip is not the same as experiencing one first hand. Few people will ever forget their first time visiting a glacier in one of Alaska's national parks.

Growing or Shrinking?

Whether glaciers grow or melt depends on several factors, including temperature and precipitation. Snow accumulates high in the mountains each winter. After many seasons of regular snowfall and cool summers, the snow that doesn't melt compacts and becomes glacier ice. When warmer temperatures or less snowfall occur, glaciers may become thinner or recede.^{xxiii}, ^{xxiv} The timing and volume of water flowing from the glacier may change dramatically as well.^{xxv}, ^{xxvi}

What's Downstream?

Changes in glacier runoff can affect streams and impact plant and animal communities. In coastal areas like Glacier Bay National Park^{xxvii}, ^{xxviii} water from glaciers contributes to a healthy ocean habitat for fish, seabirds, seals, whales, and other animals^{xxix}. This cold, fresh water contains important nutrients and sediments. Melting glacier ice, however, also contributes to the rising global sea level, spreading its impacts to coastal areas far and wide^{xxx}, ^{xxxi}.

20 Years Tracking Ice

Scientist Anthony Arendt uses satellites to study long-term changes in hundreds of glaciers around Alaska.^{xxxii} Anthony is helping the National Park Service monitor and understand changes to glaciers in Alaska's national parks^{xxxiii}. This enables the NPS and private operators to better plan for and adapt to rapid changes as they occur, especially for sites with a lot of visitor use.

Science Notes: Air in the Ice

While glaciers form, tiny bubbles of air are trapped in the ice, preserving small samples of air from the time period when the ice was formed. Scientists are able to analyze air samples from very deep ice cores in Antarctica and Greenland dating back as far as 800,000 years. They can also identify how much carbon in the bubble came from burning fossil fuels, because it has an isotopic signature that is different from other atmospheric carbon^{xxxiv}. By studying ice, scientists have confirmed that humans are adding unusually large amounts of carbon dioxide to the atmosphere and that the source of this extra carbon is from burning of fossil fuels.^{xxxv}, ^{xxxvi}

"Glaciers in Alaska probably won't disappear in the next 100 years, but they are likely to change a lot and make large contributions to rising sea levels. "I have been studying glaciers for over 20 years now, and I find it fascinating because it brings together so many elements of science. In one project, we are trying to create an

inventory of all the glaciers and ice fields in Alaska's national parks. We have also set up temperature and precipitation sensors so that we can explore the ways that glaciers may respond to climate change in the future."

- Anthony Arendt, Scientist, University of Alaska Fairbanks

Working on Ice

A scientist walks the edge of Exit Glacier with a GPS to map its perimeter. The mapped outlines are compared with 1950s-1970s USGS maps to see how park glaciers have changed.

Parks Take Action: Mapping the Ice

Glaciers cover about 5% of the state of Alaska and are in nine of Alaska's fifteen national parks. The NPS recently undertook a study to understand how glaciers are changing. Researchers mapped the edge of several glaciers and compared them to United States Geological Survey (USGS) maps from the 1950s-1970s. The results showed that glacier loss and thinning is occurring in most parks. For example, ice cover in areas surrounding Klondike decreased 18% between 1948 and 2011, and all but two Denali glaciers lost mass.^{xxxvii}

PAGE 8-9

Thawing Permafrost

Are we losing stability?

Many of Alaska's parks have a hidden underground world of ice and frozen ground. The depth and extent of this "permafrost" varies by park, depending on average air temperature, soil type, and topography, and on the types of trees and plants that grow on the surface^{xxxviii}. Can you find signs of permafrost where you are?^{xxxix}

Uncertain Footing

Frozen ground is stable, providing a solid foundation for roads and buildings. As temperatures rise, however, permafrost can thaw and sink under the weight of these structures. Permafrost can also act like a shell, trapping water in lakes and wetlands. When soils thaw, surface water can seep deeper, draining wetlands or creating holes and slumps^{xl}, ^{xli}. Lakes have drained in parks and preserves across Alaska, including Kobuk Valley, Bering Land Bridge, Noatak, Yukon-Charley Rivers, and Denali^{xlii}.

Going with the Flow

Thawing permafrost leads to drier landscapes, more frequent wildfires, and increased maintenance costs. Major investments in infrastructure can be lost when soils become unstable^{xliii}. Maintenance of roads, bridges, trails, and buildings becomes more difficult and expensive, within and outside of parklands. Denali National Park has one of the most extensive road systems of any park in Alaska and faces many of these challenges^{xliv}.

Down the Road

Tim Taylor has been working on the road crew in Denali for 31 years. He has seen a range of climate change impacts, including landform slips, slumping ground, and more rapid vegetation growth along roadsides. Permafrost thaw is at the core of many of the engineering challenges faced by Tim and his partners with the Department of Transportation.

"It seems like thawing in Denali has become more exaggerated because of climate change. In some areas the road continually moves as it thaws. Our long-term road maintenance employees have witnessed a lot of changes...They have seen increases in ground movement, especially under the park road and buildings. The tundra is now sliding down the hill toward the road, filling our ditch lines and plugging our culverts. This wasn't a problem for us back in the 70s and 80s, and it seems that in the last 15 years thawing has increased. Now every time we rebuild a section of the park road we have to account for thawing by including insulation or other components into the design to keep the road structurally sound for the future."

- Tim Taylor, Road Maintenance Foreman, Denali National Park

Where the Rubber Meets the Road

In August 2005, traffic was impeded when mud and vegetation slumped across the Denali Park Road at mile 20.5 due to thawing permafrost.

Science Notes: The Future of Permafrost

Permafrost currently exists across most of Alaska, but the amount can vary greatly^{xlv}. In the Arctic, permafrost can be hundreds to over a thousand feet thick. Permafrost in central Alaska is much thinner and more scattered^{xlvi}. Computer models make estimates about where permafrost will occur in the future^{xlvii}.

What to Look For: Thawing Ground

What signs of permafrost thaw can you observe during your visit? Ask tour operators, bus drivers, and park rangers to point out the places where the ground is sinking and slumping as underground ice thaws. Can you find cracks in the road or building foundations? Have you seen a drained lake (left) or a drunken forest (right)?

Parks Take Action

Permafrost thaw could damage some roads in parks where the average annual temperature is just a few degrees above freezing. Small changes in temperature in parks like Denali and Wrangell-St. Elias could thaw permafrost and impact structures. Research, monitoring, and mindful design is needed to respond to these changes^{xlviii}.

PAGE 10-11

Sparked by Lightning Are natural fire cycles changing?

Many visitors to Alaska are surprised to learn that wildfire is an important natural component of boreal forest and tundra ecosystems. Sparked by lightning during summer storms, fires burn older vegetation, which is soon replaced by new growth^{xlix}. Changing climate has resulted in larger fires and longer fire seasons in Alaska over the past decade^l, ^{li}.

Part of the Ecosystem

Most fires in the state occur in the spruce-dominated forests of Interior Alaska. Parks in this region include Denali, Gates of the Arctic, Wrangell-St. Elias, and Yukon-Charley Rivers. Arctic parks such as Noatak and Bering Land Bridge experience occasional large—and frequent small—tundra fires. Managing fires is a balance of protecting human lives and resources while maintaining the natural process of fire^{lii}, ^{liii}, ^{liv}.

Change Happens

Change is a natural part of the ecosystem, but change that is too rapid can have profound effects on plants, animals, and people. Some plant and animal species may have a harder time returning after more frequent, hotter, and longer fires. Grasses and shrubs benefit from ashes rich in minerals, so they show up more quickly once the fire is out. Lichens and mosses, on the other hand, are slow to return after a fire^{lv}, ^{lvi}.

Millions of Acres

The area burned in Alaska each year varies widely, ranging from a few hundred thousand to several million acres. In the past decade (2000-2009), the area burned in Alaska was twice as large as in any decade in the previous 40 years^{lvii}. Jennifer Barnes has worked as a fire ecologist for nearly 15 years, and she anticipates that with higher average air temperatures, Alaska can probably expect more frequent and larger fires.

“Fire will always be a natural force of change on the landscape, [and] climate ... has a huge impact on fires. I think there are changes going on and there are more to come. We will continue to learn about the changes, and how to manage and prepare for them.”

- Jennifer Barnes, Fire Ecologist, National Park Service

Science Notes: The Circle of Life

Fire is critical for renewing the boreal forest. Spruce trees are adapted to infrequent fires that replace them completely. Cottongrass or fireweed may be the first plants to come up after a fire. Fires that are more severe or too frequent may threaten this time-tested cycle by killing young trees, creating better conditions for invasive species, or affecting plants’ ability to colonize the burned soil^{lviii}.

What to Look For

Spruce bark beetle activity expanded after several years of warmer weather, killing thousands of acres of trees and creating maintenance challenges for Katmai National Park and Preserve, Lake Clark National Park and Preserve, and Kenai Fjords National Park^{lix}, ^{lx}. Tree foliage in damaged evergreen forests typically turns red before dropping off, even during the growing season. When seen close-up, beetle damage underneath peeling tree bark looks like a winding maze of carvings. Have you seen many dead, downed, or burned trees along the trails and roads that you are traveling? Is there smoke in the air?

Where There’s Fire, There’s Smoke

A smoke column rises from the 2012 Marie Creek Fire, which was started by lightning in Yukon-Charley Rivers National Preserve.

PAGE 12-13

Disappearing History

Can climate change lead to cultural loss in our parks?

Cultural traditions run deep in Alaska. For over ten thousand years, humans have lived on this land—including lands that are now our national parks—hunting, fishing, and gathering wood, berries, bark, and other resources. As climate alters Alaska’s plants and animals, and even the land itself, how can we protect cultural resources and history^{lxi}?

Emerging from the Ice

Animal remains...baskets...clothing...and a birch weapon estimated to be 650 years old. These and other treasures are emerging as our changing climate melts small patches of ice that have preserved them for centuries. These ice patches have attracted animals and the people who hunt them for thousands of years. Wrangell-St. Elias National Park is rich in ice patches, and archaeologists are in a race against time to find, document, and preserve archaeological resources before they are lost forever^{lxii} ^{lxiii}.

Parks Take Action: Uncovering the Past

Typically, archaeologists must interpret the past using clues from non-perishable remains such as stone and ceramics. Researchers in Lake Clark and Wrangell-St. Elias National Parks, however, are working with local residents and school children to study ancient objects found in ice patches. The knowledge possessed by Alaska Native people is helping to build a better understanding of the objects and tools that were once essential for survival in the cold north^{lxiv}.

Value Beyond Measure

In Southeast Alaska, yellow-cedar trees are an integral part of the landscape and the culture. Remarkable for its strong, decay-resistant wood, the tree is used for building homes, boats, and totem poles. Alaska Native people also

use it to make baskets, mats, masks, and paddles. For many people, the yellow-cedars hold value not only for direct uses like building or carving, but they also offer an intangible relationship to nature that contains a sense of history or a feeling of walking with one's ancestors^{lxv}.

Trees in Trouble

Lauren Oakes came to Alaska to study the yellow-cedar^{lxvi}. The trees are dying when their shallow roots freeze during late winter or early springtime cold snaps. As less snow falls on low elevation slopes, the trees no longer have enough snow to insulate and protect their roots. She wanted to know how these dying forests change over time and how the loss of this tree is affecting the local people who depend on them. Climate change, notes Ms. Oakes, does not respect the boundaries that we once thought were protected from human harm^{lxvii}.

"Here in Glacier Bay National Park, the yellow-cedars along the coast... show relatively few signs of stress... Not much farther south, I have already seen thousands of trees dying or dead."

- Lauren Oakes, PhD Candidate, Stanford University

Forests of Gray

Yellow-cedar forests are declining in Southeast Alaska, including this forest in the West Chichagof-Yakobi Wilderness just south of Glacier Bay National Park.

Pieces of History

Finds of prehistoric hunting weapons, like these arrow points, provide insights into changing environmental conditions and subsistence practices.

PAGE 14-15

Finding the Wildlife

Will there be food on the table or not?

In Alaska, national parks have unique relationships with local communities. Subsistence activities, including hunting, fishing, and gathering traditional foods, are essential to Native culture^{lxviii}, ^{lxix}. For many rural families, these practices are also a financial necessity, as groceries brought by boat or plane can be very expensive^{lxx}. Higher temperatures and shifting patterns of fire, rain, snow, and ice affect where animals are found^{lxxi}.

Food from the Land

Almost 300 small communities in Alaska cannot be reached by road. Many of them are within or adjacent to national parks. These communities are largely inhabited by Alaska Native people who have centuries-long traditions of relying on the land for food. How much food? About 7,000 moose and 22,000 caribou are harvested for subsistence and non-subsistence purposes in Alaska each year, amounting to 6 million pounds of meat^{lxxii}.

Protecting Traditions

Residents of many of Alaska's parks depend on moose, caribou, salmon, birds, marine mammals, and other animals for food. This traditional way of life is protected by federal law. But changes in snow cover, sea ice, or the timing of river freeze-up affect the ability of people to reach the animals they harvest. Changes in wildfire or extreme weather events may also influence hunting success and animal health^{lxxiii}. Does climate trump law?

Seasons out of Sync

John Chase grew up hunting and fishing near Bethel. John has observed some changes in the seasons that disrupt the food chain. He describes how: *"It will rain or snow when it's not supposed to. When you get rain on a winter day it's never good, because ice will cover the plants that caribou forage on...I've even heard of ice trapping*

ptarmigan underneath...if the caribou aren't able to forage and feed because of that layer of ice, there are going to be hungry and unhealthy caribou."

"I'd like to let folks know that we have a spiritual connection to the land, and that we depend on a healthy environment for survival. If there are changes to the environment, we are going to adapt to those changes. One thing that will not change is our dependence on animals for food...food security is priority number one. For us, the important questions are about food security. Will there be food on the table?"

- John Chase, Community Planner, Northwest Arctic Borough

Parks Take Action

In collaboration with many partners, NPS is monitoring the Western Arctic Caribou Herd^{lxxiv, lxxv}. The goal is to better understand the behavior, breeding patterns, and seasonal movements of this extremely important subsistence species, which is found throughout the northwest arctic parks and surrounding lands. Climate change could have profound effects on the timing or routes of the herd's migrations.^{lxxvi}

Science Notes: Subsistence Foods in Alaska

The average citizen in the arctic coastal community of Kivalina consumes nearly 600 pounds of wild foods in a year. These foods come from a wide variety of animals and plants, including bearded seals, beluga whales, caribou, and blueberries. Subsistence foods are culturally and economically important in Alaska. Subsistence foods are shared among communities and families, and they provide many important health benefits to the people who eat them. (Figure: 2007 data from Alaska Department of Fish & Game)^{lxxvii}

What to Look For: Food from Land and Sea

Depending on where you are in Alaska, different wild foods make up different portions of people's diets. Many foods are dried, such as salmon, or frozen, so they can be eaten all year long. What kinds of foods have you seen or tasted during your visit?

Animals on the Move

The habitat of the Western Arctic Caribou Herd covers all of northwestern Alaska, where many residents identify themselves as "caribou people."^{lxxviii} Caribou use different park units at different times of the year, and their migration patterns are altered by changes to the climate and the landscape. Here caribou graze the late summer grasses and lichen in Bering Land Bridge National Preserve.

PAGE 16-17

Loading the Dice

Is climate change taking our weather to extremes?

Unusual weather events such as winter rains and ice storms are affecting parks in Alaska like Bering Land Bridge^{lxxix}, Gates of the Arctic^{lxxx}, and Yukon-Charley Rivers National Preserve^{lxxxi}. Although it is not possible to link any specific flood, storm, or heat wave to climate change, increasing temperatures may be "loading the dice" in favor of extreme storms, floods, and fires^{lxxxii}.

Hazard Zones

Understanding what extreme events will be like in the future can be challenging, because there is so much uncertainty about how climate change will impact the frequency, intensity, and even the types of weather events. In Alaska, extreme weather events frequently threaten people, wildlife, or infrastructure^{lxxxiii}. Weather forecasts are especially important for people traveling on remote highways, in small planes, or on boats.

Rehearsing the Future

Warm air holds more moisture than cold air. Warmer water in the air, in lakes and streams, and in the ocean stores more energy, which can fuel weather events or increase a storm's intensity. Understanding weather influences like this allows us to plan in the face of uncertainty. By examining a range of possible scenarios, and potential "tipping points," we can look for solutions that make sense regardless of which situation arises, and plan accordingly^{lxxxiv}.

The Price Tag

Many of the social and economic costs associated with climate change will come from shifts in the severity and frequency of extreme weather events. In general, climate change happens gradually and is described in terms of averages. Extreme events, however, can be sudden, hard to predict, and serious. Preparation for unusual floods, droughts, heat waves, or storms can help protect lives, preserve critical resources, and save money over the long-term^{lxxxv}.

"Extreme events are, and always have been, a part of our weather and climate. However, climate change involves an observable shift in the severity and frequency of extreme events. In the 25 years I have worked as a meteorologist in Alaska, I have seen background conditions that are much different than when I was a young man. If our experience no longer serves us, then we have less information to help people and communities prepare for and cope with weather events."

- Rick Thoman, Weather Forecaster, National Weather Service Alaska

Parks Take Action

When two towns near Yukon-Charley Rivers National Preserve were hit hard by flooding from the ice-jammed Yukon River in the spring of 2009, park rangers had an Incident Command team on site^{lxxxvi}. Their proactive approach helped local residents. They rescued two people and a 24-dog mushing team from a home threatened by the flood. Although a great deal of property was damaged or destroyed, the rangers' actions helped prevent further losses^{lxxxvii}.

Get Involved!

Many people confuse weather (short-term events) with climate (long-term patterns). To learn more about the difference between weather and climate, scan the QR code or use the link below to watch National Geographic's useful video on the subject: <http://video.nationalgeographic.com/search?q=climate-weather-sci>

An Uncommon Flood

Ice jams can be extremely destructive and can easily demolish structures. When the Yukon River flooded the community of Eagle in the spring of 2009, ice and water swept away homes and destroyed historic buildings. The US Customs house, where Jack London and Wyatt Earp once signed the US Customs book (below), had stood unharmed on the banks of the Yukon River for over 100 years.

PAGE 18-19

Losing Ground

Are coastal communities and cultures at risk?

As permafrost disappears and sea ice forms later in the year, coastal communities become more susceptible to storms. Unprotected by sea ice, shorelines are hammered by waves and winds from autumn storms, resulting in unprecedented rates of coastal erosion that could sweep away dozens of buildings and homes within the next few years^{lxxxviii}. Some communities are trying to relocate to more inland locations^{lxxxix}.

Soft Soil, Hard Choices

Shishmaref is home to about 600 people. The small community is located on a barrier island off the coast of Alaska near Bering Land Bridge National Preserve. The seas that surround the island no longer freeze before the arrival of powerful fall and winter storms. Storm waves batter the vulnerable coastline, causing hundreds of feet of erosion. The erosion damages buildings and washes away property^{xc}. Coastal erosion also threatens our ability to preserve the ancient archeological evidence of America's first inhabitants in Cape Krusenstern National Monument and other parks^{xcii}, ^{xciii}.

Communities at Risk

In 2004, Shishmaref resident Luci Eningowuk testified before the U.S. Senate. "To date, we have lost numerous storage buildings and boats, an ATV, two snowmachines, meat-drying racks, and buried food. Tragically, we have lost one home; so far we have been able to move 18 threatened homes. However, those of us living here know that it is merely a matter of time before we experience greater losses. We are quickly running out of space on our ever-shrinking island."^{xciii}

Born in Shishmaref, Fred Tocktoo now lives in Nome, where he has worked at the Bering Land Bridge National Preserve since 1992. In his lifetime, he has seen major changes in weather patterns, particularly in their unpredictability.

"The ice conditions are so unstable that people don't venture out more than three or four miles from the mainland nowadays. Everything changes in a minute... When we were growing up, we had sort of a weather pattern that was stable, but now you can't trust it. Fifty or sixty years ago, it was stable [enough] that you were almost guaranteed that if you were going to go from Shishmaref to Wales, you get there in 3 days by dog team. Now, with faster snowmachines, you get there in 3 hours, but within those 3 hours the weather can change two or three times."
- Fred Tocktoo, Bering Land Bridge National Preserve

Get Involved!

Are there local, regional, or national venues where your voice can be heard? Writing letters to lawmakers or to your local paper can be a meaningful way to take action.

Science Notes: Sea Ice on the Decline

Satellite images and climate models show continued retreat and thinning of arctic sea ice. By 2030, late summers could be nearly ice-free in the Arctic^{xciv}. This dramatic decline is in part a result of longer warm seasons. The sea ice extent in September 2012 was 1.3 million square miles less than the historical average^{xcv}. In addition to affecting the national parks, loss of sea ice raises many new issues in the Arctic. Increasing ship traffic, tourism, and development make environmental safety and security important issues for the United States and other arctic nations^{xcvi}, ^{xcvii}.

Living on the Edge

Many rural communities are located along the coast of Alaska. Thawing permafrost and shrinking sea ice make homes and communities vulnerable as coastlines erode, and some villages that have been inhabited for hundreds of years now face evacuation.

PAGE 20-21

The Acid Test

Are marine species in trouble?

Climate change is making the world's oceans more acidic^{xcviii}. Changes in ocean chemistry could affect marine food webs and the people who rely on them^{xcix}. With five times more coastline than any other state, Alaskans are

particularly dependent on the ocean^c. Twelve of Alaska's national parks are on or near the coast, and the NPS is monitoring these waters to help protect ocean resources and livelihoods^{ci}.

Ocean Acidification

Carbon moves around our planet naturally, cycling through the atmosphere, land, and oceans. In the past century, largely due to the burning of fossil fuels, carbon dioxide has increased dramatically in the atmosphere. The oceans absorb some of the excess carbon dioxide. The elevated levels of carbon dioxide in the oceans reduce the pH of the water—an effect known as ocean acidification^{cii}.

Species at Risk

Ocean acidification makes it harder for many marine organisms, such as corals, zooplankton, and shellfish to form their skeletons or protective shells^{ciii}. This has negative effects on other species in the food web that rely on them. Pteropods, free-swimming marine snails and slugs, can make up more than half the diet of young salmon^{civ}, and are particularly sensitive. Species differ in their sensitivity to pH, so there is a lot to learn about how this will affect marine resources^{cv}.

Sampling the Depths

Claudine Hauri is a researcher at the University of Alaska. She has been studying ocean acidification using data collected at sea from many different depths and locations. Despite the extent of her work, she urges that far more research is needed to better understand ocean acidification and the species at risk. She explains that the future is uncertain because “organisms react differently...and in Alaska, not many organisms have been studied.”

“The global ocean surface pH used to be 8.2 and now it has dropped by 0.1 [about a 30% increase in acidity]. This is a big deal for some organisms because some are very sensitive to small changes in their chemical environment. The biggest challenge we face is multiple stressors...it's all interconnected.”

- Claudine Hauri, Scientist, University of Alaska Fairbanks

Parks Take Action: Acidification Research

In Glacier Bay National Park and Preserve, researchers from the University of Alaska Fairbanks (UAF) have been studying ocean acidification^{cvi}. Glaciers have been melting here over the last 250 years, and the amount of freshwater entering Glacier Bay is increasing. By measuring seawater chemistry at sites with varying levels of glacier melt water, researchers hope to better understand the relationship between glacier runoff and ocean acidification^{cvi}. In the photo, UAF graduate student Stacy Reisdorph lowers a water sampling instrument into the icy waters of Glacier Bay.

Science Notes: Acidification in the North

Although changes in ocean pH are occurring worldwide, the effects are more pronounced in Alaska for a couple of reasons. First, colder water absorbs more carbon dioxide^{cvi}. Second, the waters that circulate toward Alaska on prevailing ocean currents are already high in natural carbon dioxide because living things have released the gas all along the water's long journey^{cix}.

Get Involved

If you have questions about the world around you, the NPS can help you find answers. They fund internships, fellowships, and citizen science programs to look at the effects of climate change. Scan the QR code or use the link to find more information: www.nps.gov/subjects/climatechange/internshipsandresearch.htm

Below the Surface

Sea butterflies, a type of pteropod, have winglike lobes for swimming. They are sensitive to decreasing ocean pH because acid causes their shells to dissolve. These tiny, delicate creatures are the base of the marine food web. Whatever affects them affects all of the animals that rely on them for food—including salmon.

Test the Waters

Oceanographers lower instruments (left) to collect water samples from various locations and depths at sea. The samples are analyzed to determine the water's pH, temperature, salinity, and other characteristics.

PAGE 22-23

The Future is Now

Alaska's National Parks lead by example

The NPS is working to minimize its carbon footprint. Because carbon dioxide remains in the atmosphere for several decades, temperatures will continue to rise until we dramatically reduce carbon emissions. With impacts already being felt in parks and nearby communities, park managers and local residents must continue to find ways to respond, adapt, and lead efforts to slow climate change^{cx}.

Rethinking Actions

National parks provide a means to think about what is possible in our communities and in our everyday lives. Parks have traditionally been managed to preserve unique habitats, important systems, or remnants of our past. As the climate changes, preserving specific habitats, cultural features, or species may become impossible^{cxⁱ}. In what ways must we change? Learning to do things differently may not be easy. Alaska's park managers are using climate change scenario planning as one tool for exploring different ways the future may unfold^{cxⁱⁱ}.

Leading by Example

Recent innovations in Alaska's parks include new energy systems, electric and hybrid vehicle fleets, and higher standards for recycling waste. At Kenai Fjords, electricity for the Nature Center is generated by a hydrogen fuel cell^{cxⁱⁱⁱ}; at Klondike Gold Rush in Skagway, a fleet of electric maintenance vehicles are powered by hydroelectric power generated from the runoff of melting glaciers^{cx^{iv}}; and at Glacier Bay, recycling now accounts for almost 60% of the total waste stream for the park^{cx^v}. With these efforts, the parks are making a difference and saving money at the same time.

Building Knowledge

As the evidence and understanding of the effects of climate change have become better known, so have the approaches for discussing them with our audiences. Surveys of visitors and local business operators about their perceptions of climate change have helped improve the messages and their delivery. Throughout the state, interpreters and scientists are working together to raise awareness about this issue, provide the best available scientific explanations of its impacts, and cultivate a hopeful response that moves us collectively into the future^{cx^{vi}}.

"The past will not be our guide to a future with climate change."

- Jeff Mow, Park Superintendent

Building a Better Future: Denali Takes Action

Denali National Park and Preserve is a National Park System Center for Environmental Innovation^{cx^{vii}}. The park showcases new technologies, motivates and educates the public and park service employees about environmentally friendly practices, and works to cut energy use and reduce environmental impacts. This integrated approach to address climate change is just one example of the NPS Green Parks Plan^{cx^{viii}}, an integrated approach to address climate change through sustainable practices.

What to Look For

Look critically at your trip, your home, and the services you use. Where are the recycling bins? Can you see alternate fuels being used? Do you see hybrids and electric vehicles in use? Do you see inefficiencies at the parks you visited? Challenge the NPS to improve ongoing efforts in energy reduction, recycling, and more.

Power from the Sun

Solar panels at the Eielson Visitor Center in Denali National Park helped the building achieve platinum level certification from the Leadership in Energy and Environmental Design (LEED) program—the highest standard for energy efficiency^{cxix}.

PAGE 24

A Shared Journey

What will the parks be like for our grandchildren?

We are in the early steps of a long journey, learning to adapt to Earth’s changing climate even as we work together to slow that change^{cxx}. This journey will unfold over decades and will likely result in a significantly different way of life for most of us, regardless of where we live.

Alaska’s National Parks are living laboratories and communities for understanding, appreciating, and protecting a continually changing environment and our natural heritage^{cxxi}. Join the conversation, and make a difference. Throughout this visitor guide, we have suggested ways you can learn more, identify change, get involved, and take action^{cxii}. Some of the most crucial include:

Join the Conversation!

Sharing the impacts of climate change that you have seen first-hand in Alaska can help galvanize action by others, regardless of where they live.

Ask Tough Questions

Business owners, elected officials, and other organizations make choices that affect us all. Your voice is important and needed.

Cultivate Hope

Together, we can succeed. This guide is a starting place. A digital version of this book is also available, and you can read the reports and papers that we have referenced.

Learn more:

Download the expanded digital “State of Change” iBook and browse references:

www.nps.gov/akso/nature/climate/state-of-change.cfm

For more about the National Park Service, climate change, and actions you can take:

www.nps.gov/climatechange

This publication represents a joint effort of the National Park Service (NPS) Alaska Region and the Scenarios Network for Alaska and Arctic Planning (SNAP), part of the International Arctic Research Center at the University of Alaska Fairbanks. UAF is an AA/EO employer and educational institution.

-
- ⁱ The Rio Earth Summit: Summary of the United Nations Conference on Environment and Development. Prepared by Stephanie Meakin, Science and Technology Division, November 1992 <http://publications.gc.ca/Collection-R/LoPBdP/BP/bp317-e.htm>
- ⁱⁱ National Park Service. 2010b. Alaska Region Climate Change Response Strategy 2010-2014. National Park Service, Alaska Region, Anchorage, Alaska. Available from <http://www.nps.gov/akso/docs/AKCCRS.pdf> (accessed 14 April 2014).
- ⁱⁱⁱ Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007. North America. Climate Change 2007: Impacts, Adaptation and Vulnerability. Pages 617-652 in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson, editors. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.
- ^{iv} Intergovernmental Panel on Climate Change (IPCC). 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, R.K. Pachauri, and A. Reisinger, editors. IPCC, Geneva, Switzerland.
- ^v Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. *Conservation Biology* 17: 358-366.
- Schwartz, P. 1996. *The Art of the Long View: Planning for the future in an uncertain world*. Doubleday, New York, New York.
- ^{vi} National Park Service. Climate Change Conversations. <http://www.nps.gov/subjects/climatechange/climate-change-conversations.htm>
- ^{vii} National Park Service. How can we have harsh winters and global warming at the same time? <http://www.nps.gov/stories/climatequestion06.htm>
- ^{viii} Wohlforth, Charles P. 2004. *The whale and the supercomputer : on the northern front of climate change*. New York. North Point Press. 322 pp.
- ^{ix} National Park Service. Do scientists agree about climate change? <http://www.nps.gov/stories/climatequestion02.htm>
- ^x W. R. L. Anderegg, "Expert Credibility in Climate Change," *Proceedings of the National Academy of Sciences* Vol. 107 No. 27, 12107-12109 (21 June 2010); DOI: 10.1073/pnas.1003187107.
- ^{xi} P. T. Doran & M. K. Zimmerman, "Examining the Scientific Consensus on Climate Change," *Eos Transactions American Geophysical Union* Vol. 90 Issue 3 (2009), 22; DOI: 10.1029/2009EO030002.
- ^{xii} N. Oreskes, "Beyond the Ivory Tower: The Scientific Consensus on Climate Change," *Science* Vol. 306 no. 5702, p. 1686 (3 December 2004); DOI: 10.1126/science.1103618.
- ^{xiii} U.S. Global Climate Change Research Program <http://www.globalchange.gov/home>
- ^{xiv} Global Carbon Project <http://www.globalcarbonproject.org/>
- ^{xv} National Park Service Climate Change Internships and Research <http://www.nps.gov/subjects/climatechange/internshipsandresearch.htm>
- ^{xvi} National Park Service, Capturing History in the Beach Ridges of Cape Krusenstern <http://www.nps.gov/stories/cakrbeachridges.htm>
- ^{xvii} National Park Service, The Science of Climate Change in National Parks Video Series. <http://www.nps.gov/subjects/climatechange/sciencevideos.htm>
- ^{xviii} National Park Service. Explaining Climate Change Videos. <http://www.nps.gov/subjects/climatechange/explainingccvideos.htm>
- ^{xix} Pearson, Paul N., and Martin R. Palmer. 2000. Atmospheric carbon dioxide concentrations over the past 60 million years. *Nature* 406, 695-699 (17 August 2000).
- ^{xx} Climate Change and Your National Parks. <http://www.nps.gov/subjects/climatechange/index.htm>
- ^{xxi} Project Jukebox. Digital Branch of the University of Alaska Fairbanks Oral History Program. "William "Bud" Rice. Exit Glacier, Kenai Fjords National Park. December 10, 2010. <http://jukebox.uaf.edu/site7/p/580>
- ^{xxii} National Park Service. Field Notes: The Changing Face of Exit Glacier <http://www.nps.gov/media/video/view.htm?id=BB060818-1DD8-B71C-07BF2B4C1FE658E9>
- ^{xxiii} Repeat Photography of Alaskan Glaciers. USGS. http://www.usgs.gov/climate_landuse/glaciers/repeat_photography.asp

-
- xxiv National Park Service. Glacial Mass Balance. <http://www.nps.gov/olym/naturescience/interactive-glacier-glacial-mass-balance.htm>
- xxv Arendt, A., S. Luthcke, R. Hock (2009). Glacier Changes in Alaska: Can Mass Balance Models Explain GRACE mascon trends? *Annals of Glaciology*. 50, 1-7.
- xxvi Loso, Michael G., Anthony Arendt, Chris Larsen, Nate Murphy, and Justin Rich. Chapter 4: Status and Trends of Alaska National Park Glaciers. *Alaska Park Science*. Volume 12 Issue 2 <http://www.nps.gov/stories/trends-of-alaska-national-park-glaciers.htm>
- xxvii Kaste, Martin. July 03, 2008. 12:01 AM ET. National Public Radio. Glacier Bay Park's Gravity Shifts As Ice Melts <http://www.npr.org/templates/story/story.php?storyId=91894873>
- xxviii Chang, Kenneth. The Big Melt Accelerates. May 19, 2014. The New York Times. http://www.nytimes.com/2014/05/20/science/the-melting-isnt-glacial.html?_r=0
- xxix Neal, Edward G., Eran Hood, and Kathy Smikrud. Contribution of glacier runoff to freshwater discharge into the Gulf of Alaska. *Geophysical Research Letters*. Volume 37, Issue 6. 17 March 2010. <http://onlinelibrary.wiley.com/doi/10.1029/2010GL042385/pdf>
- xxx Sea Level Rise. National Geographic. <http://ocean.nationalgeographic.com/ocean/critical-issues-sea-level-rise/>
- xxxi SOTC: Contribution of the Cryosphere to Changes in Sea Level. National Snow and Ice Data Center. http://nsidc.org/cryosphere/sotc/sea_level.html
- xxxi Arendt, Anthony. Geophysical Institute. University of Alaska, Fairbanks. <http://www.gi.alaska.edu/profile/anthony-arendt>
- xxxi Arendt, Anthony and Chris Larsen. National Park Service. Natural Resource Stewardship and Science. Alaskan National Park Glaciers--Status and Trends. First Progress Report. Natural Resource Data Series NPS/AKR/NRDS 2012/403. http://science.nature.nps.gov/im/units/sean/AuxRep/GD/GD_ProgressReport_NRDS_2012-403.pdf
- xxxi National Research Council (NRC), 2006. Surface Temperature Reconstructions For the Last 2,000 Years. National Academy Press, Washington, DC.
- xxxi Dyurgerov, Mark B. and Mark F. Meier. February 15, 2000. Twentieth century climate change: Evidence from small glaciers. *The National Academy of Sciences*. vol. 97 no. 4 1406–1411. <http://www.pnas.org/content/97/4/1406.short>
- xxxi Arendt, A., J. Walsh, W. Harrison (2009). Changes of Glaciers and Climate in Northwestern North America during the Late 20th Century. *Journal of Climate*. 22, 4117-4134.
- xxxi Arendt, Anthony, and Chris Larsen. Alaskan National Park Glaciers-- Status and Trends. Third Progress Report. National Park Service. Natural Resource Data Series NPS/AKRO/NRDS. 2013/439.
- xxxi National Park Service. Denali National Park and Preserve. Permafrost Landscapes <http://www.nps.gov/dena/naturescience/upload/Permafrost-Landscapes.pdf>
- xxxi Romanovsky, Vladimir, Sergey Marchenko, and Santosh Panda. Permafrost modeling in Alaskan National Park Lands. Project duration: 2011 – 2016. Permafrost Laboratory, Geophysical Institute, University of Alaska Fairbanks. <http://permafrost.gi.alaska.edu/project/permafrost-modeling-alaskan-national-park-lands>
- xi National Park Service. Permafrost. <http://www.nps.gov/akso/nature/environment/permafrost.cfm>
- xli Swanson, David K. National Park Service. Natural Resource Stewardship and Science. Monitoring of Retrogressive Thaw Slumps in the Arctic Network, 2011. Natural Resource Report NPS/ARC/NRDS—2012/2472011. <http://www.nps.gov/akso/nature/documents/NRDS247slump3D2012.pdf>
- xlii Larsen, Amy. Understanding lake drainage in northern Alaskan national parks: Impacts of a warming climate. *Park Science*. Published: 15 Jan 2014 (online) 30 Jan 2014 (in print). <http://nature.nps.gov/ParkScience/index.cfm?ArticleID=414&ArticleTypeID=22>
- xliii Thawing Permafrost. A Student's Guide to Global Climate Change. U.S. Environmental Protection Agency. <http://www.epa.gov/climatestudents/impacts/signs/permafrost.html>
- xliv Permafrost: Denali's Frozen Ground in Transition. Denali Center for Resources, Research, and Learning - May 2012. <http://www.nps.gov/dena/naturescience/upload/Schirokauer-Permafrost-Resources-Day-5-2012.pdf>
- xlvi Jorgenson MT, Osterkamp TE (2005) Response of boreal ecosystems to varying modes of permafrost degradation. *Can J For Res* 35:2100–2111.
- xlvi Shur YL, Jorgenson MT (2007) Patterns of permafrost formation and degradation in relation to climate and ecosystems. *Permafr Periglac* 18(1):7–19 CrossRef
- xlvii Panda, Santosh K.; Sergey S. Marchenko; Vladimir E. Romanovsky. High-resolution permafrost modeling in Denali National Park and Preserve. National Park Service. Natural Resource Technical Report. NPS/CAKN/NRTR—2014/858.

-
- xlvi Vinson, Ted S. Mitigation Options to Reduce Icing and Thaw Instability Problems on the Denali Park (Alaska) Access Road. *Journal of Glaciology and Geocryology*. 2005-01.
- xlvi Role of Fire in Alaska. Role of Fire 2007 UNIT I. National Fish and Wildlife Service. National Wildlife Refuge System. <http://www.fws.gov/alaska/nwr/visitor/fire/PDFs/Unit%201%20-%20Forest%20and%20Tundra%20Ecology.pdf>
- l Flannigan et al., 2000. M.D. Flannigan, B.J. Stocks, B.M. Wotton. Climate change and forest fires. *Sci. Total Environ.*, 261 (2000), pp. 221–229.
- li Ryan Kelly, Melissa L. Chipman, Philip E. Higuera, Ivanka Stefanova, Linda B. Brubaker, and Feng Sheng Hu Recent burning of boreal forests exceeds fire regime limits of the past 10,000 years *PNAS* 2013 110: 13055-13060.
- lii Barnes, Jennifer. National Park Service Fire Ecology Annual Report, Alaska Region, Calendar Year 2013. <http://www.nps.gov/akso/nature/fire/documents/2013-AKR-Annual-Report-Fire-Ecology-Final-Web.pdf>
- liii National Park Service. Alaska Regional Office. Wildland Fire. <http://www.nps.gov/akso/nature/fire/index.cfm>
- liv Abatzoglou, J.T., and T.J. Brown. 2011. A comparison of statistical downscaling methods suited for wildfire applications. *International Journal of Climatology* 32 (5): 772-780.
- lv Rowe JS, Scotter GW (1973) Fire in the boreal forest. *Quat Res* 3:444–464.
- lvi Jandt, Randi R.; Joly, Kyle; Rupp, T. Scott. 2006. Effects of climate warming on tundra fire ecology: Poor forecast for caribou? (Poster). 3rd International Fire Ecology and Management Congress; November 13-14, 2006.
- lvii Alaska Climate Change Adaptation Series. Wildfires. University of Alaska Fairbanks Cooperative Extension Service. June 2013. <http://www.uaf.edu/files/ces/publications-db/catalog/cred/ACC-00100.pdf>
- lviii Chapin, F. S., M. W. Oswood, K. Van Cleve, L. A. Viereck, and D. L. Verbly, eds. 2006. *Alaska's changing boreal forest*. New York: Oxford Univ. Press.
- lix Berg, E. E., J. D. Henry, C.L. Fastie, A.D. De Volder and S.M. Matsuoka. (2006). "Spruce beetle outbreaks on the Kenai Peninsula, Alaska, and Kluane National Park and Reserve, Yukon Territory : Relationship to summer temperatures and regional differences in disturbance regimes." *Forest ecology and management* 227(3): 219-232.
- lx Egan, Timothy. On Hot Trail Of Tiny Killer In Alaska. *New York Times*. June 25, 2002 <http://www.nytimes.com/2002/06/25/science/on-hot-trail-of-tiny-killer-in-alaska.html>
- lxi National Park Service. Alaska Regional Office. History & Culture. <http://www.nps.gov/akso/history/index.cfm>
- lxii Dixon, E. James, Craig M. Lee, William F. Manley, Ruth Ann Warden, and William D. Harrison 2007. The Frozen Past of Wrangell-St. Elias National Park and Preserve. *Alaska Park Science* 6:24-29. <http://www.nationalparkstraveler.com/files/WRST-Artifacts.pdf>
- lxiii Vanderhoek, Richard, E. James Dixon, Nicholas L. Jarman, and Randoulph M. Tedor. Ice Patch Archaeology in Alaska: 2000–10 Arctic, Vol. 65, Supplement 1: The Archaeology and Paleocology of Alpine Ice Patches (2012), pp. 153-164.
- lxiv AAA Conference Gives Life to Ancient Stories and New Revelations. *Frontier Scientists*. March 26th, 2013. <http://frontierscientists.com/tag/lake-clark-nps/>
- lxv Hennon, Paul. Dying Yellow Cedars. *Living on Earth*. Air Date: Week of February 17, 2012. <http://www.loe.org/shows/segments.html?programID=12-P13-00007&segmentID=6>
- lxvi Oakes, Lauren. Humans and Nature: Can the Gulf Be Bridged? (Sep 13, 2012); Hunting for Debris and Answers in Alaska (Aug 28, 2012); Snapshots in Time: The Dynamics of Trees (July 23 2012); Along a Verdant Shore, a Vision of Past, Present and Future (July 11 2013); In the Wild, Seeking an Answer: What Replaces Dying Trees? (June 13, 2012). *Green: Energy, the Environment, and the Bottom Line*. The New York Times. <http://green.blogs.nytimes.com/author/lauren-e-oakes/>
- lxvii Oakes, Lauren, Paul Hennon, Rodolfo Dirzo, Eric Lambin and Kevin O'Hara. Yellow-cedar on Glacier Bay National Park's Outer Coast. Research Highlights. Glacier Bay National Park and Preserve. National Park Service. Fall 2013. <http://www.nps.gov/glba/naturescience/upload/Oakes-2013-Highlight-FINAL-web.pdf>
- lxviii McLean, Deborah L. Rural Alaska Native Perceptions of Cultural Transmission: Implications for Education. Spring 1997. *Journal of American Indian Education*. Volume 36 Number 3.
- lxix National Park Service. Gates of the Arctic National Park & Preserve Alaska. Subsistence: Preserving a Way of Life. <http://www.nps.gov/gaar/historyculture/subsistence.htm>
- lxx Goldsmith, Scott. Understanding Alaska's Remote Rural Economy. January 2008. UA Research Summary No. 10. Institute of Social and Economic Research. University of Alaska Anchorage http://www.iser.uaa.alaska.edu/Publications/researchsumm/UA_RS10.pdf
- lxxi Callaway, Dan. Effects of Climate Change on Subsistence Communities in Alaska. National Park Service, Anchorage, Alaska. <http://www.besis.uaf.edu/besis-oct98-report/Subsistence.pdf>
- lxxii Managing Alaska's Wildlife. 2010 Report. Division of Wildlife Conservation

Alaska Department of Fish & Game

http://www.adfg.alaska.gov/static/home/library/pdfs/managing_alaskas_wildlife.pdf

lxxiii Alaska Sea Grant Marine Advisory Program. Climate Change and Subsistence: What It Means to Alaskans and How We Can Adapt. University of Alaska Fairbanks. <https://seagrant.uaf.edu/map/climate/docs/subsistence.php>

lxxiv Monitoring the Western Arctic Caribou Herd. Caribou Resource Brief. National Park Service, Alaska Regions, Inventory and Monitoring Program, Arctic Network.

<http://www.nps.gov/kova/blogs/upload/CaribouResourceBrief.pdf>

lxxv Rogers, Jillian. May 24, 2014. Decline of Western Arctic caribou herd raises questions about hunting, proposed road. Alaska Dispatch News. <http://www.adn.com/article/20140524/decline-western-arctic-caribou-herd-raises-questions-about-hunting-proposed-road>

lxxvi Sharma, S., Couturier, S. and Côté, S. D. (2009), Impacts of climate change on the seasonal distribution of migratory caribou. *Global Change Biology*, 15: 2549–2562.

lxxvii Magdanz, James S., Nicole S. Braem, Brad C. Robbins, and David S. Koster. 2010. Subsistence Harvests in Northwest Alaska, Kivalina and Noatak, 2007. Technical Paper No. 354. Alaska Department of Fish and Game, Division of Subsistence. <http://www.subsistence.adfg.state.ak.us/techpap/tp354.pdf>

lxxviii Western Arctic Caribou Herd Working Group. <http://westernarcticcaribou.org/>

lxxix Thiessen, Mark. March 22, 2011 9:19:31 PM ET. At Least 32 Musk Oxen Freeze to Death After Alaska Storm. NBC News. Associated Press. http://www.nbcnews.com/id/42222099/ns/us_news-environment/t/least-musk-oxen-freeze-death-after-alaska-storm/#.VDMWNBbWf6c

lxxx Nielsen, Laura. April 29th, 2014. Thousands of kilometers north – migratory birds and a shifting world. *Frontier Scientists*. <http://frontierscientists.com/2014/04/thousands-of-kilometers-north-migratory-birds-shifting-world/>

lxxxi Repanshek, Kurt. Floods Sweeping Gateways to Yukon-Charley Rivers National Preserve. May 5, 2009 - 7:02pm. National Parks Traveler. <http://www.nationalparkstraveler.com/2009/05/floods-sweeping-gateways-yukon-charley-rivers-national-preserve>

lxxxii Rosen, Yereth. May 6, 2014. Climate change effects magnified in Alaska, says federal report. Alaska Dispatch News. <http://www.adn.com/article/20140506/climate-change-effects-magnified-alaska-says-federal-report>

lxxxiii National Climate Assessment. Chapter 22: Alaska. U.S. Global Change Research Program. <http://nca2014.globalchange.gov/highlights/regions/alaska#storylink=relat>

lxxxiv National Park Service, Alaska Regional Office. "Rehearsing the Future" - Scenario Planning in Alaska <http://www.nps.gov/akso/nature/climate/scenario.cfm>

lxxxv Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change. 2012. Cambridge University Press.

New York, NY. Intergovernmental Panel on Climate Change. http://www.ipcc.ch/pdf/special-reports/srex/SREX_Full_Report.pdf

lxxxvi Chunks of Floating Ice Tear Up Alaska Town. NBC News. May 7, 2009 5:58:11 P.M. ET.

<http://www.nbcnews.com/id/30619771/ns/weather/t/chunks-floating-ice-tear-alaska-town/#.VDMccxbWf6c>

lxxxvii Hopkins, Kyle (The Village). May 6, 2009, 12:46 pm. 10 p.m. update, from Eagle: River up another 3 feet. Anchorage Daily News. <http://community.adn.com/adnode/140969>

lxxxviii Atkinson, David. Understanding Coastal Erosion in Alaska. Alaska Center for Climate Assessment and Policy (ACCAP). University of Alaska Fairbanks. Webinar. <https://accap.uaf.edu/?q=webinar/understanding-coastal-erosion-alaska>

lxxxix Goldenberg, Suzanne. The state we're in: How climate change is stealing the ground from beneath Alaskans' feet. *America's Climate Refugees*. The Guardian.

<http://www.theguardian.com/environment/interactive/2013/may/15/alaska-erosion-climate-change>

xc Sutter, John D. Climate change threatens life in Shishmaref, Alaska. December 3, 2009 3:39 a.m. EST. CNN.

http://www.cnn.com/2009/TECH/science/12/03/shishmaref.alaska.climate.change/index.html?eref=rss_tech

xc Lawler, Jim. Coastal erosion in the Arctic Network. Coastal Erosion Resource Brief. National Park Service. Alaska Region Inventory & Monitoring Program.

http://www.nps.gov/akso/nature/documents/briefs/RB_ARCN_CoastEros_Jan11_FINAL.pdf

xcii Tworek-Hofstetter, Miriam. September 10, 2013. Climate Change at Cape Krusenstern. National Center for Preservation Technology and Training. National Park Service.

<http://ncptt.nps.gov/blog/climate-change-case-study-cape-krusenstern-national-monument-ak/>

-
- ^{xciii} Senate Hearing 108-808. June 29, 2004. Alaska Native Village Erosion. Hearings before the Committee on Appropriations, United States Senate, One Hundred Eighth Congress, Second Session. <http://www.gpo.gov/fdsys/pkg/CHRG-108shrg95486/html/CHRG-108shrg95486.htm>
- ^{xciv} O'Rourke, Ronald. August 4, 2014. Changes in the Arctic: Background and Issues for Congress. Congressional Research Service. <http://fas.org/sgp/crs/misc/R41153.pdf>.
- ^{xcv} Viñas, Maria-José. September 8, 2014. Four decades of sea ice from space: The decline. NASA: Global Climate Change. <http://climate.nasa.gov/news/1154/>
- ^{xcvi} Parry, Wynne. September 20, 2012 09:54am ET. What Sea-Ice Loss Means for Development in the Arctic. LiveScience. <http://www.livescience.com/23344-melting-arctic-ocean-development.html>
- ^{xcvii} What Future for the Arctic? New Awareness and Opportunities for UNEP to Address Climate Change in the Arctic. February 18, 2013. Nairobi, Kenya. A Background Paper for the Arctic Side Event at the Governing Council/Global Environmental Ministerial Forum. <http://www.unep.org/gc/gc27/Docs/se/What%20Future%20for%20the%20Arctic.pdf>
- ^{xcviii} Ocean Acidification: The Other Carbon Dioxide Problem. PMEL Carbon Program. NOAA. <http://www.pmel.noaa.gov/co2/story/Ocean+Acidification>
- ^{xcix} The Ocean Portal Team; Reviewed by Jennifer Bennett (NOAA). Ocean Acidification. <http://ocean.si.edu/ocean-acidification>
- ^c Alaska's Fishing Industry. Resource Development Council. <http://www.akrdc.org/issues/fisheries/overview.html>
- ^{ci} National Park Service Alaska Regional Office. Inventory and Monitoring. <http://www.nps.gov/akso/nature/science/monitoring.cfm>
- ^{cii} Effects of Changing the Carbon Cycle. NASA Earth Observatory. <http://earthobservatory.nasa.gov/Features/CarbonCycle/page5.php>
- ^{ciii} Kennedy, Caitlyn. Thursday, October 29, 2009. An Upwelling Crisis: Ocean Acidification. NOAA Climate. <https://www.climate.gov/news-features/features/upwelling-crisis-ocean-acidification>
- ^{civ} Welch, Laine. May 1, 2014. NOAA: First evidence of acid oceans harming pteropods=45% of pink salmon diet. <http://www.alaskafishradio.com/noaa-first-evidence-of-acid-oceans-harming-pteropods45-of-pink-salmon-diet/>
- ^{cv} FAQs about ocean acidification. EPOCA: European Project on Ocean Acidification. <http://www.epoca-project.eu/index.php/what-is-ocean-acidification/faq.html>
- ^{cvi} Rosen, Yereth. April 29, 2014 Researchers examine glaciers' effects on ocean acidification in Prince William Sound. Alaska Dispatch News. <http://www.adn.com/article/20140429/researchers-examine-glaciers-effects-ocean-acidification-prince-william-sound-0>
- ^{cvii} Ocean Acidification Research Center. School of Fisheries and Ocean Sciences. University of Alaska Fairbanks. <https://www.sfos.uaf.edu/oarc/index.php>
- ^{cviii} Chu, Jennifer. Storing Carbon in the Arctic. December 4, 2013. MIT News Office <http://eapsweb.mit.edu/news/2013/storing-carbon-arctic>
- ^{cix} Rahmstorf, Stefan. 2006. Thermohaline Ocean Circulation. In: Encyclopedia of Quaternary Sciences, Edited by S. A. Elias. Elsevier, Amsterdam.. http://www.pik-potsdam.de/~stefan/Publications/Book_chapters/rahmstorf_eqs_2006.pdf
- ^{cx} National Park Service. 2010b. Alaska Region Climate Change Response Strategy 2010-2014. National Park Service, Alaska Region, Anchorage, Alaska. Available from <http://www.nps.gov/akso/docs/AKCCRS.pdf> (accessed 14 April 2014).
- ^{cxii} Marris, E. 2011. Rambunctious Garden: Saving nature in a post-wild world. Bloomsbury, New York, New York.
- ^{cxiii} National Park Service. 2010a. National Park Service Climate Change Response Strategy. National Park Service Climate Change Response Program. National Park Service, Fort Collins, Colorado. Available from http://www.nps.gov/climatechange/docs/NPS_CCRS.pdf (accessed 10 June 2012).
- ^{cxii} Peterson, G.D., G.S. Cumming, and S.R. Carpenter. 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation Biology 17: 358–366.
- Schwartz, P. 1996. The Art of the Long View: Planning for the future in an uncertain world. Doubleday, New York, New York.
- ^{cxiii} Prototype Propane Fuel Cell Passes Muster In Alaska. Science Daily. University of Alaska Fairbanks. November 14, 2006. <http://www.sciencedaily.com/releases/2006/11/061113170844.htm>

-
- ^{cxiv} National Park Service. Klondike Gold Rush. Klondike Gold Rush National Historical Park wins Second Place in Green Parks Video Contest <http://www.nps.gov/klgo/parknews/klondike-gold-rush-national-historical-park-wins-second-place-in-green-parks-video-contest.htm>
- ^{cxv} Ohlson, Jake. Managing Solid Waste in a Remote Facility. National Park Service. Glacier Bay National Park & Preserve [http://yosemite.epa.gov/R10/ECOCOMM.NSF/b8015c7aa2a4743a8825742b006e7e86/8fc546de4a54fba4882576a90063f46f/\\$FILE/Managing%20Solid%20Waste%20in%20a%20Remote%20Facility.pdf](http://yosemite.epa.gov/R10/ECOCOMM.NSF/b8015c7aa2a4743a8825742b006e7e86/8fc546de4a54fba4882576a90063f46f/$FILE/Managing%20Solid%20Waste%20in%20a%20Remote%20Facility.pdf)
- ^{cxvi} Jezierski, C., R. Loehman, and A. Schramm. 2010. Understanding the science of climate change: Talking points - impacts to Alaska Maritime and Transitional. Natural Resource Report NPS/NRPC/NRR—2010/223. National Park Service, Fort Collins, Colorado.
- ^{cxvii} National Park Service. Denali. The Eielson Visitor Center. <http://www.nps.gov/dena/planyourvisit/the-eielson-visitor-center.htm>
- ^{cxviii} National Park Service. Green Parks Plan. <http://www.nps.gov/greenparksplan/>
- ^{cxix} National Park Service. Sustainable Buildings. <http://www.nps.gov/sustainability/sustainable/>
- ^{cxx} Walters, C.J. 1986. Adaptive Management of Renewable Resources. Blackburn Press, New York, New York.
- ^{cxxi} Cole, D.N., and L. Yung. 2010. Beyond Naturalness: Rethinking park and wilderness stewardship in an era of rapid change. Island Press, Washington, DC.
- ^{cxxii} National Park Service. Do my actions really matter? <http://www.nps.gov/stories/climatequestion09.htm>